Formidable Challenges to Teaching Advanced Laparoscopic Skills

Marelyn Medina, MD

ABSTRACT

Despite the acceptance of laparoscopy for performing routine operations, a need still exists for experienced surgeons and surgical residents to maintain and refine essential surgical skills. Unless used on a frequent basis, laparoscopic skills are not easily maintained. In addition, when new laparoscopic instruments are introduced, surgeons need a way to practice using them that does not involve immediate patient contact. Novice surgeons need the most training of all and ideally would be best served using a standardized teaching curriculum that would cover as many of the basic laparoscopic parameters as possible. This article discusses how best to set up a laparoscopic simulation training program that covers as much ground as necessary, while respecting the restraints of time limitations and monetary concerns.

Key Words: Laparoscopy, Laparoscopic training, Surgical skills.

Address reprint request to: Marelyn Medina, MD, The Family Urology Center, 412 E. Dove Avenue, McAllen, TX 79504, USA. Telephone: (956) 686-7243, Fax: (956) 668-7123, E-mail: mmedinamd@aol.com

INTRODUCTION

A curriculum consisting of short practice sessions would help experienced surgeons and surgical residents maintain and refine "essential surgical skills." Several steps, though, are required before such a program can be established. First, the essential surgical skills common to all specialties must be identified and then the physical restraints that influence the teaching of these basic skills must be noted. This is essential for determining how many "lesson plan units" will be required. Regardless of the skill being taught, accompanying text, drawings, or video clips will be needed for explanation purposes. One lesson plan unit consists of either of these visual aids, or a combination of them.

Essential surgical skills must be defined as either basic skills or advanced skills, with the latter using the former as a foundation. For example, the placement of a simple suture involves practice first using a laparoscopic needle holder to engage different types of needles. Next, needle advancement must be achieved through the two tissue borders to be approximated. Finally, mastery at tying suture ends to obtain tissue approximation must be acquired. Once these basic skills are mastered, the surgeon can then perform advanced skills such as interrupted or continuous anastomoses on different organ structures.

Physical restraints also have a bearing on teaching essential surgical skills. In open surgery, the major restriction is improper exposure. Once proper isolation of the operative field is achieved, hand movements proceed easily. In laparoscopy, the situation is entirely the opposite. Exposure is excellent, but the surgeon's movements are labored. Patient and surgeon body habitus, port placement, instrument length, and instrument handles can present major obstacles during laparoscopy.

STUDY OBJECTIVES

If all essential surgical skills and their affecting physical restraints are identified and taken into consideration, can an all-inclusive curriculum be developed?

MEANS AND METHODS

Although some disagreement might exist as to the order of importance in teaching essential surgical skills, the following order is suggested: 1) Knot tying; 2) Simple interrupted suturing; 3) Simple running suturing; 4) Purse string suturing; 5) End-to-end anastomosis; 6) End-to-side anastomosis; 7) Side-to-side anastomosis; 8) Use of stapling devices; 9) Catheterization of ductal structures.

Two types of physical restraints affect the performance of laparoscopic procedures. Some physical restraints must be taken into account at all times. These can be called "general physical restraints." The second subset involves parameters that will depend on the essential surgical skill being practiced on at the time. These can be called "particular physical restraints."

Five general physical restraints exist **(Table 1)** that were never encountered in open surgery but that are always present in laparoscopic surgery. They are considered inherent to the very nature of the technology and present unique challenges to surgeons. Understanding them is essential in trying to develop teaching models as well as in creating new instruments.

Excessive instrument length is a new surgical parameter unique to laparoscopy and the possible cause of fatigue and injury to a surgeon's upper extremities. In contrast to open surgery, where the surgeon's hands are almost always hovering over the operative site at convenient angles, in laparoscopy limited port position restricts the surgeon's hands to distant and narrow working angles. What is won as a benefit in video surgery with increased magnification and exposure is lost in the lack of flexibility of motion and increased fatigue.

Because the surgeon's hands are closer to the operative site in open surgery, less energy is used in moving the instrument working jaws. This is in direct contrast to laparoscopic surgery where the hands are a considerable distance from the operative site, requiring a greater expenditure of energy to perform the same maneuvers. An analogy of this situation is seen in **Figure 1**. Imagine that you have two people on a record turntable starting at position A and B, A being at a greater distance from the center C than B. For both to maintain the same amount of rotations per minute, which will result in A going to A' and B going to B', it will require A to travel a longer distance at a faster velocity and greater energy expenditure, than it will for B. The physics involved in this model is directly applicable to the physics of laparoscopy. As a result, it requires more energy to operate a longer instrument than a shorter one.

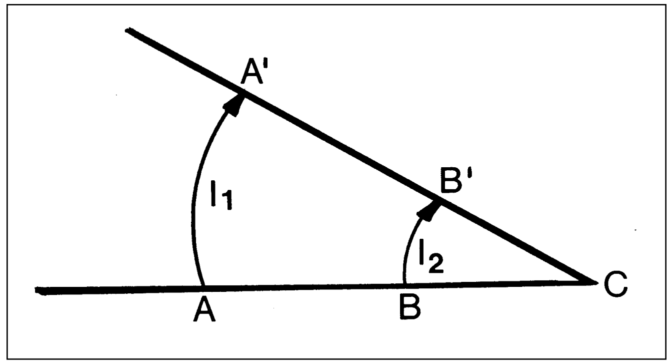

Figure 1. Travel around a fixed point C. Arc distance AA' is greater than BB'.

Table 1.
General Physical Restraints.

1. Excessive instrument length
2. Rotational effects
3. Variations in tissue plane angles
4. Specimen orientation
5. Depth perception

Rotational effects seriously hamper training efforts and are related to the standing position of the surgeon in relation to the camera view projected on the monitor. It is not enough to practice skills, such as suturing and knot tying, in the camera position alone, but also in the right camera position, left camera position, and the opposite camera position. This is essential because the movements necessary to tie a knot in one position are entirely different from those needed to tie the same knot in another. To practice advanced skills in only the camera position and to forget the other positions is impractical when performing videoscopic surgery that requires the use of assistants to help retract and assist in important surgical maneuvers. Everyone cannot be located at the camera position when only one camera is being used.[1]

Variations in tissue plane angles are evident because of the cavernous nature of the operative field in videoscop-

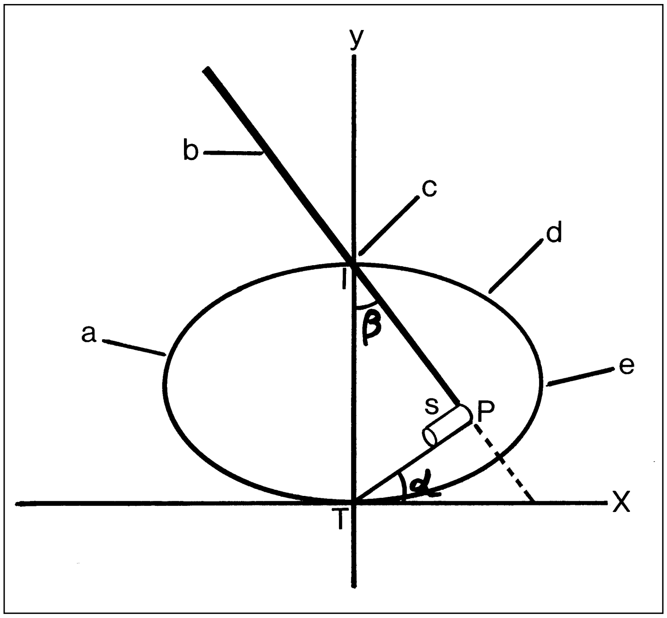

Figure 2. Mathematical representation of important laparoscopic angles and planes. α: Tissue angle, β: Instrument angle, TP: Tissue plane, IP: Instrument plane, S: tubular specimen, a: diaphragm, b: instrument shaft, c: entry port, d: abdominal wall, e: pelvic side wall, X: patient horizontal axis, Y: patient vertical axis.

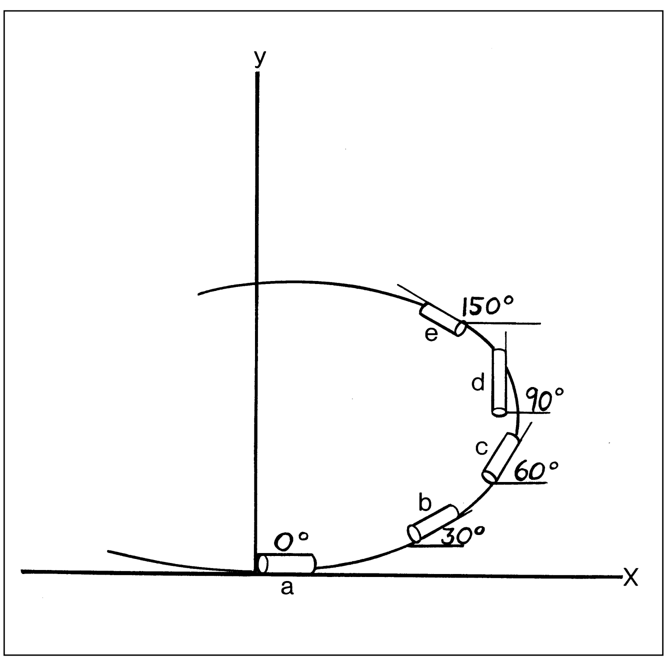

Figure 3. Representation of several tissue angles along the abdominal cavity.

ic surgery. For example, when performing a laparoscopic bladder neck suspension procedure, placing a simple suture in the periurethral tissues requires a different set of maneuvers than placing the same suture on Cooper's ligament, which is approximately 90 degrees up the pelvic sidewall. A repair of an anterior abdominal wall ventral hernia might conceivably require placing sutures while aiming up to the ceiling from the site of entry ports. Performing surgery in the thoracic cavity would also result in similar restraints. A simulation model must provide practice sessions in all the possible varying tissue plane angles that the videoscopic surgeon might encounter in actual practice.

Two angles are important in laparoscopy. The first is α, the tissue angle, which is defined as that angle between the tissue plane being worked on and the patient's horizontal axis. The second is β, the instrument angle, which is the angle between the shaft of the laparoscopic instrument and the patient's vertical axis. These angles are represented in **Figures 2 and 3**. A cylindrical drawing is used to represent tubular structures, such as vessels, ducts, or bowel.

TP represents the tissue plane, and IP represents the instrument plane. The α angle will vary according to the anatomical structure being worked on. Although variations may exist among the α angles of organs in individuals, for the most part they will be similar. The β angle will vary greatly, depending on the trocar insertion site. The ideal angles to provide maximum flexibility and minimum surgeon fatigue are yet to be worked out. To simulate variations in tissue plane angles, a special device to hold practice specimens is needed. It must permit placing all types of specimens in as many angles from the horizon as possible.

Specimen orientation has to do with how, for instance, a tubular structure, such as a bowel or a vessel, lies on the particular plane it is on. This is independent of the angle of the tissue plane. It represents a rotational effect intrinsic to the tissue. **Figure 4** illustrates this concept of orientation. Here the tissue plane, at angle α, is demonstrated as TP extending to T'P' along the patient's third dimensional axis z. Within the two-dimensional plane, three tubular structures, a, b, and c, are placed. In relationship to the surgeon's point of view on the monitor, they lie at either a horizontal, vertical, or oblique position.

Table 2.
Particular Physical Restraints.

1. Needles shape: Curved or straight
2. Suture type: Braided or monofilament
3. Suture size: Large or small
4. Suture material: soft or stiff
5. Suture designs: Straight or looped
6. Specimen type: Organic meats or synthetic models
7. Handedness of surgeon: Right-handed or left-handed
8. Surgical approach: Intracorporeal or extracorporeal
9. Type of pelvic trainer: Closed box, ring, computer simulation

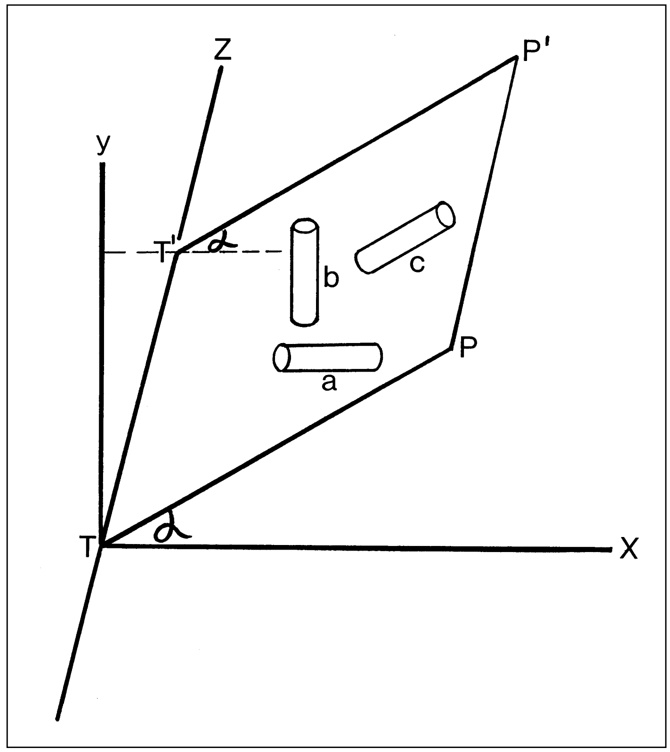

Figure 4. Specimen orientation at tissue angle a. A: horizontal, b: vertical c: oblique. X: patient horizontal axis, Y: patient vertical axis, Z: 3rd dimensional axis perpendicular to X & Y.

In open surgery, if tissue rotation is off, the surgeon instinctively rearranges his field or himself to provide better exposure. Unfortunately, this luxury is not always available in laparoscopy, and the surgeon must learn to work in undesirable orientations to do the job.

Depth perception errors arise from the fact that we work in three-dimensional space, but when performing videoscopic surgery, the monitor image is a two-dimensional replication of the operative field. So, if we are tying a suture using a monitor display, we often run into the problem of determining how close up or far away a suture end is from the rest of the suture length we are working with. It requires practice to observe important landmarks to determine what part of a suture lies in front and what part lies immediately behind adjacent structures before knot tying can be performed effortlessly.

In addition to the five general physical restraints mentioned above, various other particular physical restraints exist **(Table 2)** that come into consideration when developing a video training program. These are important factors that affect the number of lesson plan units to be developed and reflect the personal preferences of both the student and the teacher. Just as in open surgery, we all have our own particular way of performing a series of actions so too in videoscopic surgery these differences also exist. This is not a matter of a right or wrong way of doing things, but merely represents the fact that there is more than one way to accomplish a goal.

Needle shape is important in facilitating entry into tissue planes and in interacting with the needle holder. The size of the needle also has an impact on the ease or difficulty encountered in manipulating it.

The type of suture used and the suture size will depend on the tissue being worked on. Tying ease will vary in different situations. Polyfilament sutures are usually easier to tie than monofilament sutures. The suture material likewise has a bearing on its tying flexibility. Some materials are softer and hold a knot better than others. The suture design can vary from a classic straight suture or one with loops built in to facilitate handling and eliminate some of the motions of tying.[2]

The handedness of the surgeon must be taken into consideration as well because the hand movements of each will be completely different, requiring additional specific drawings or video clips, depending on whether the surgeon is right-handed or left-handed.

Surgical approach concerns the ability to tie a knot either completely intracorporeally with instruments versus assisted extracorporeal hand directed suture tying. In the latter, some form of "pusher" goes in and out of one of the ports to tighten the knot.

The type of trainer used will depend on the surgeon's preferences and funding. The original "pelvic trainers" are limited devices with static port entries. They are made of either clear or opaque materials that may permit the surgeon to see the practice field. Modern ring trainers allow greater flexibility in port location and specimen selection.[3]

Computerized simulation trainers have created excitement recently. The expense associated with maintaining their function unfortunately is far beyond what most hospitals or solitary practitioners can afford. Their main importance appears to lie in the computer technology that allows a surgeon to operate by means of robotics from a distant location.[4] A major concern about this technology is what happens when a mechanical malfunction occurs in the middle of a critical operation, and the only persons in the room, besides the patient, are an anesthesiologist and a mechanic. Who is going to stop the bleeding then?

RESULTS

Using some of the variables involved in both the general and particular physical restraints as a guide, let us see how many lesson plan units would be needed to do a thorough job of teaching how to tie a vessel intracorporeally. A fairly inclusive approach would take into consideration the following parameters:

(2) Type of pelvic trainers: opaque box and ring
(4) Standing position: camera, right camera, left camera, and opposite camera
(3) Tissue plane angle: 0°, 30°, and 90°
(3) Specimen orientations: horizontal, vertical, and oblique
(2) Specimen model: artificial and animal tissue
(2) Suture material: polyfilament or monofilament
(2) Suture size: large: 0 and small: 4-0
(2) Suture design: straight and looped
(2) Handedness: right and left

To obtain the total number of lesson plan units needed to do a fairly thorough job of teaching the essential surgical skill of tying off a vessel, we need to multiply the above numbers in parenthesis together. The total equals 2x4x3x3x2x2x2x2x2 = 2,304. This is the total number of lesson plan units needed to do a reasonably thorough job of teaching how to tie a vessel, while taking into consideration the aforementioned general and physical restraints. Although this number appears large, it still does not include all the variables of individual preferences that might still exist.

A more limiting approach would be to restrict the parameters as follows:

(1) Type of pelvic trainer: ring
(1) Standing Position: camera
(1) Tissue plane angle: 30°
(2) Specimen orientations: horizontal and vertical
(1) Specimen model: artificial
(1) Suture material: silk
(1) Suture size: large: 2-0
(1) Suture design: looped
(1) Handedness: right

By limiting training sessions to only the above physical restraints, our total number of lesson plan units now comes down to 1x1x1x2x1x1x1x1x1 = 2. These two lesson plan units would consist of video clips or still photographs accompanied by descriptive text. The description of these two lesson plan units is as follows:

Lesson Plan Unit 1 demonstrates a right-handed surgeon using a ring simulation device to practice vessel tying by an intracorporeal technique with a 2-0 silk looped suture while standing in the camera position. The artificial vessel specimen is at a 30° inclination and lying in a horizontal orientation.

Lesson Plan Unit 2 demonstrates a right-handed surgeon using a ring simulation device practicing vessel tying by an intracorporeal technique with a 2-0 silk looped suture while standing in the camera position. The artificial vessel specimen is at a 30° inclination and lying in a vertical orientation.

CONCLUSION

The previous analysis leads us to believe that an all-inclusive curriculum can never be developed. If teaching one essential surgical skill thoroughly requires over 2,000 lesson plan units, then to teach even 5 would result in the need for 10,000. To be completely thorough, the course would take years to develop and years for surgeons to perform all the lessons. By necessity to maintain reasonable time and monetary schedules, training courses will always have to be limited arenas for surgeons to practice in.

DISCUSSION

The fact that an entirely all-inclusive laparoscopic training course cannot be developed does not mean we should abandon the concept. What course directors must continue to do is concentrate on those areas of expertise they are most familiar with while remaining open to the fact that other ways may exist for performing similar techniques. The fact is that whatever is being covered in any one course may actually be just a small part of the knowledge that is still to be uncovered.

Because laparoscopic surgery training is such a paradox, we must constantly be on guard against establishing "gold standards," as we have done in open surgery. This technology is still in its infancy, and its final chapter is unwritten. If we try to standardize operations, we will freeze progress and inhibit surgeons from attempting new and far better approaches to current laparoscopic procedures.

What is needed is to add to the current excellent clinical training courses available, a method that allows surgeons to practice essential surgical skills in well-defined limited lesson plan units using an inexpensive laparoscopic simulation device. By this means, surgeons can then take the initiative for themselves to further fine tune course-acquired skills preferably in a trainer that allows variation of as many of the previously mentioned physical parameters as possible.

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